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Energetics of semi dry rice influenced by nutrient and weed management

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Abstract
A field experiment was conducted at Agricultural College, Aswaraopet, Bhadradri Kothagudem, Telangana during *Kharif* 2016 to evaluate the effect of nutrient and weed management under semi dry rice in Sandy clay loam soil. The experiment was laid out in a split plot design with three replications comprising of three nutrient and four weed management practices. Grain and straw yield and harvest index recorded was significantly higher in 75% RDF+25% N through Vermicompost and FYM over 100% RDF. Application of herbicides coupled with hand weeding recorded significantly superior grain and yield and harvest index compared to sole application of herbicides or control. Similar pattern of higher energy output, net energy, energy productivity, energy use efficiency was noticed with different nutrient and weed treatments. On contrary, energy intensity in physical and economic terms followed an opposite trend.

Keywords: Semi dry rice, energy, nutrient and weed management

1. Introduction

Rice (*Oryza sativa* L.) is a primary food crop grown widely in more than 100 countries of the world. Almost 90% of the world's rice is produced and consumed in Asia to provide up to three-fourths of the total calories required by 520 million Asians. Globally in 2020, rice is grown in an acreage of 162.06 m ha with production of 755.47 mt and productivity of 4661 kg ha^{-1} (FAOSTAT, 2019-20). Rice occupies an area of 43.66 m. ha with production and productivity of 118.87 mt and 2723 kg ha^{-1} respectively in India. In Telangana, rice is grown in an area of 3.19 m. ha with production of 11.12 mt and productivity of 3483 kg ha^{-1} (CMIE, 2019-20). To overcome the constraints in transplanted rice *viz.*, nursery, puddling, transplanting, irrigation and labor ultimately enhanced cost of cultivation as well as delayed monsoon or late onset of canal water release made farmers to switch over to semi dry rice. In semidry system, rice is treated as a rainfed crop for around 40-45 days before being converted to a wet crop when enough water is available (Chatterjee and Maiti, 1985) [1], (Kumar and Ladha, 2011) [9] and (Dhanapal *et al*., 2018) [4].

The nutrient management exploits initial vigour of the varieties, enhances nutrient supply for good crop establishment (Parasivmurthy *et al*., 2012) [17]. In semi dry rice, due to the concurrent crop and weed growth, absence of standing water in the initial crop establishment phase aggravates weed insurgence and critical period of weed competition has been reported to be 15-60 days after seeding (Chauhan and Mahajan, 2014) [2] in dry direct seeded Rice. Efficient weed management a key to success in semi dry rice (Kapila Shekawat *et al*., 2020) [7]. Keeping this in view of these facet, the present investigation is chosen with the objective to enhance the sustainability and productivity of the soil and crop with the adoption of different nutrient and weed management practices in semi dry rice for Central Telangana Zone.

2. Materials and Methods

Field experiment was carried out during *Kharif* 2016 at Agricultural College, Aswaraopet, Bhadradri Kothagudem, Telangana. The experimental site was sandy clay loam texture with pH (6.72), EC (0.36 dS m^{-1}), low in OC (0.41%), N (204.5 kg ha^{-1}), medium in available P_2O_5 (29.1 kg ha^{-1}) and K_2O (273 kg ha^{-1}). The cultivar tested was KNM 118 with a spacing of 20 cm x 15 cm. Treatmental details of split plot design with three replications, three main plots of nutrient management (M_1 - 100% RDF, M_2 - 75% RDF + 25% N through Vermicompost and M_3 - 75% RDF + 25% N through FYM) while, subplots were assigned to four levels of weed management (S_1 – Control, S_2 - Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* hand weeding at 20, 40 DAS, S_3 - Bispyribac sodium 10 SC @ 25 g ha^{-1} (Early PoE.) *fb* (Fenoxa-prop-p-ethyl 62.5 g ha^{-1} + 2, 4 – D

80 WP 0.5 kg ha^{-1}) at 35-40 DAS and S_4 - Bispyribac sodium 10 SC @ 25 g ha^{-1} (PE) *fb* (Pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4 – D 80 WP 0.5 kg ha^{-1}) + HW at 50 DAS in semi dry rice during *kharif* season 2016. Recommended dose of fertilizer (150:50:40 N, P_2O_5, K_2O kg ha^{-1}) was applied in the form of urea, SSP and MOP. The crop was harvested manually with the help of sickles.

2.1. Yield: Grain and straw yield in kg ha^{-1} was measured from each net plot after threshing, cleaning and drying of the grain.

Harvest index = Economic yield /Biological yield *100

2.2. Energetics
2.2.1 Energy input
Energy input of different nutrient and weed management practices of rice was estimated by using direct and indirect energy (Singh and Mittal, 1992) [20]. Direct energy inputs include total quantity of fossil fuel used in land preparation, harvesting, human labour and electricity while indirect energy inputs are energy used in production of machinery and raw materials like mineral fertilizers, pesticides and seed energy inputs and transportation. A complete inventory of all crop inputs (fertilizers, seeds, plant protection chemicals, fuels, human labour, irrigation water and, machinery power) and outputs of both grain and straw yield was recorded. Energy input in different treatments was computed by multiplying the input with the corresponding energy coefficients and summing up of all these.

2.2.2 Energy output: The grain and straw yields were considered for calculating output energy. Energy output was calculated by multiplying the grain and straw yields with corresponding energy coefficient.

$$\text{Net energy} = \text{energy output} - \text{energy input}$$

$$\text{Energy use efficiency (\%)} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

$$\text{Energy productivity (Kg MJ}^{-1}) = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

$$\text{Energy intensity in physical terms (MJ Kg}^{-1}) = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Biological yield (kg ha}^{-1})}$$

$$\text{Energy intensity in economic terms (Rs MJ}^{-1}) = \frac{\text{Gross energy output (MJ ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

All the data were subjected to analysis of variance (ANOVA) as per the standard procedure. The Treat mental means were compared with critical difference (CD) at 5%.

3. Results and Discussion
3.1. Grain, straw yield and harvest index
The impact of nutrient and weed management practices on grain and straw yield and their interaction was noteworthy as presented in table 1 and fig. 1. However, effect of nutrient management and interaction between nutrient and weed management did not show any significant effect on harvest index. As per nutrient management practices, 75% RDF + 25% N through Vermicompost *i.e.* M_2 recorded highest grain and straw yield which was at par with 75% RDF + 25% N through FYM followed by M_1 [100% RDF].

Under weed management sub plots, Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* (Pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4-D 80 WP 0.5 kg ha^{-1}) + HW at 50 DAS *i.e.* S_4 produced enhanced grain, straw output and harvest index which was followed by S_2, S_3 and least in S_1. S_2 and S_4 had statistically similar results.

Combination with 75% RDF and 25% N through Vermicompost or FYM provided slow and continuous release of better nutrients to the crop at different growth intervals, allowing the crop to assimilate adequate photosynthetic products, resulting in increased dry matter, source and sink capacity and ultimately grain and straw yield. The findings agreed with those of Neha Sharma *et al*. (2021) [14] and Meena Hemaraj *et al*. (2019) [11]

An integrated weed management approach with the hand weeding and herbicides with different mode of actions to combat weed menaces in semi dry rice and prevent changes in weed community structure throughout the crop growth period might have improved source and sink capacity *viz.*, no. of panicles m^{-2} and total no. of grains $panicle^{-1}$, which expedited higher production of grain and straw output as stated by Sylvestre Habimana *et al*. (2019) [22].

3.2. Energetics
3.2.1. Energy input
The energy input influenced by different nutrient and weed management practices was same in the two years and presented in the table 2. Among nutrient treatments, highest energy was spent in M_1 [100% RDF] and it was followed by M_3 *i.e.* 75% RDF + 25% N through FYM and lowest energy input was noticed in M_2 [75% RDF + 25% N through Vermicompost].

Among weed management practices higher energy was expended in S_3 [Bispyribac sodium 10 SC 25 g ha^{-1} (Early PoE) *fb* (Fenoxaprop-p-ethyl 62.5 g ha^{-1} + 2,4 – D 80 WP 0.5 kg ha^{-1}) at 35 - 40 DAS] which was followed by S_4 [Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* (Pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4-D 80 WP 0.5 kg ha^{-1}) + HW at 50 DAS] and S_2 [Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* hand weeding at 20 and 40 DAS]. While the lowest energy was consumed in S_1**.** More energy was expended in sole application of chemical fertilizers which might have led to higher energy input. The results were corroborated by Priyanka Sinha *et al*. (2018) [15] and Thirupathi *et al*. (2018) [23].

Higher energy input might be due to consumption of a greater number of labours for manual weeding. These results were substantiating with Rajendra Prasath *et al*. (2020) [16] and Lavanya *et al*. (2019) [10].

3.2.2. Energy output, net energy, energy productivity and energy intensity

Amidst nutrient management practices, M_2 *i.e.* 75% RDF + 25% N through Vermicompost] ensued the highest energy output, net energy, energy use efficiency and energy productivity followed by M_3 *i.e.* 75% RDF + 25% N through FYM, whereas M_1 [100% RDF] had the lowest energy values. However, M_2 and M_3 were at par with output and net energy. On the contrary, chemically fertilized treatment produced maximum energy intensity in economic and physical terms subsequently M_3 and M_2. All the three nutrient treatments registered statistically similar values of energy intensity (Table 2, fig. 2 and fig. 3).

Regarding weed treatments, S_4 [Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* (Pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4-D 80 WP 0.5 kg ha^{-1}) + HW at 50 DAS] resulted in the highest energy output, net energy, energy use efficiency and energy productivity, which was statistically similar to S_2 [Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* hand weeding at 20 and 40 DAS] and significantly superior over S_3 [Bispyribac sodium 10 SC 25 g ha^{-1} (Early PoE) *fb* (Fenoxaprop-p-ethyl 62.5 g ha^{-1} + 2,4 – D 80 WP 0.5 kg ha^{-1}) at 35 - 40 DAS]. Under Control, the lowest energy values of the above parameters were noted in the research study. In contrast to these energy values, maximum returns of energy intensity in economic terms were fetched by $S_2 > S_4 > S_3 > S_1$ in the order of descent while reverse trend of $S_1 > S_3 > S_2 > S_4$ was detected as far as energy intensity in physical terms was concerned.

Higher energy use efficiency was observed due to constant supply of nutrients throughout the crop growth period as a result of conjunctive use of manures and fertilizers might have resulted in enhanced output and low energy consumption most likely resulted in obtaining the greatest energy output. Similar findings have been reported by Mohanty *et al* (2014) [13] and Mohanty *et al* (2013) [12], Lavanya *et al*. (2019) [10] and Yadav *et al*. (2018) [25]. These results were substantiating with Priyanka Sinha *et al*. (2018) [15] and Hussain *et al*. (2013) [6].

Higher energy intensity in economic terms with 100% chemical fertilizers might be due to increased total energy input. Similar results were corroborated by Rakesh Kumar *et al*. (2019) [18] and Thirupathi *et al*. (2018) [23]. Increased overall energy input may be the cause of higher energy intensity in physical terms with 100% chemical fertilizers. Rakesh Kumar *et al*. (2019) [18] found undifferentiated results.

Highest energy output may be due to efficient weed control *i.e.* combined application of pre-emergence, post emergence herbicides and hand weeding might have probably, registered higher crop output and lower energy use, as stated by Vijayagouri (2019) [24], Ravi (2017) [19] and Kaur and Singh (2016) [8]. Higher yield with low energy input might have resulted in high energy use efficiency under weed free situation. Higher energy output to input ratio with sequential application of herbicides was also reported by Rajendra Prasath *et al*. (2020) [16] and Sreedevi *et al*. (2015) [21]. Control plot which is unweeded throughout the crop growth displayed higher energy intensity which might be due to less straw output. The results corroborate the findings of Kaur and Singh (2016) [8].

Table 1: Grain and straw yield (kg ha^{-1}) of semi dry rice influenced by nutrient and weed management (*Kharif*, 2016).

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Main plots: Nutrient Management			
M_1	3197	4106	42.7
M_2	4060	4811	44.9
M_3	3702	4635	43.4
Mean	3653	4518	43.7
S.Em±	100	104	1.4
CD @5%	394	408	NS
Sub plots: Weed Management			
S_1	1828	2919	38.3
S_2	4619	5298	46.6
S_3	3320	4417	42.9
S_4	4845	5436	47.1
Mean	3653	4518	43.7
S.Em±	91	92	1.2
CD @5%	270	275	3.6
Interaction			
M × S			
S.Em±	157	160	2.1
CD @5%	468	476	NS
S × M			
S.Em±	196	200	2.7
CD @5%	560	574	NS

Nutrient Management

M_1 – 100% RDF

M_2 – 75% RDF + 25% N through Vermicompost

M_3 - 75% RDF + 25% N through FYM

Weed Management

S_1 - Control

S_2 - Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* hand weeding at 20, 40 DAS

S_3 - Bispyribac sodium 10 SC 25 g ha^{-1} (Early PoE) *fb* (Fenoxaprop-p-ethyl 62.5 g ha^{-1} + 2, 4 – D 80 WP 0.5 kg ha^{-1}) at 35-40 DAS

S_4 - Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* (Pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4 – D 80 WP 0.5 kg ha^{-1}) HW at 50 DAS

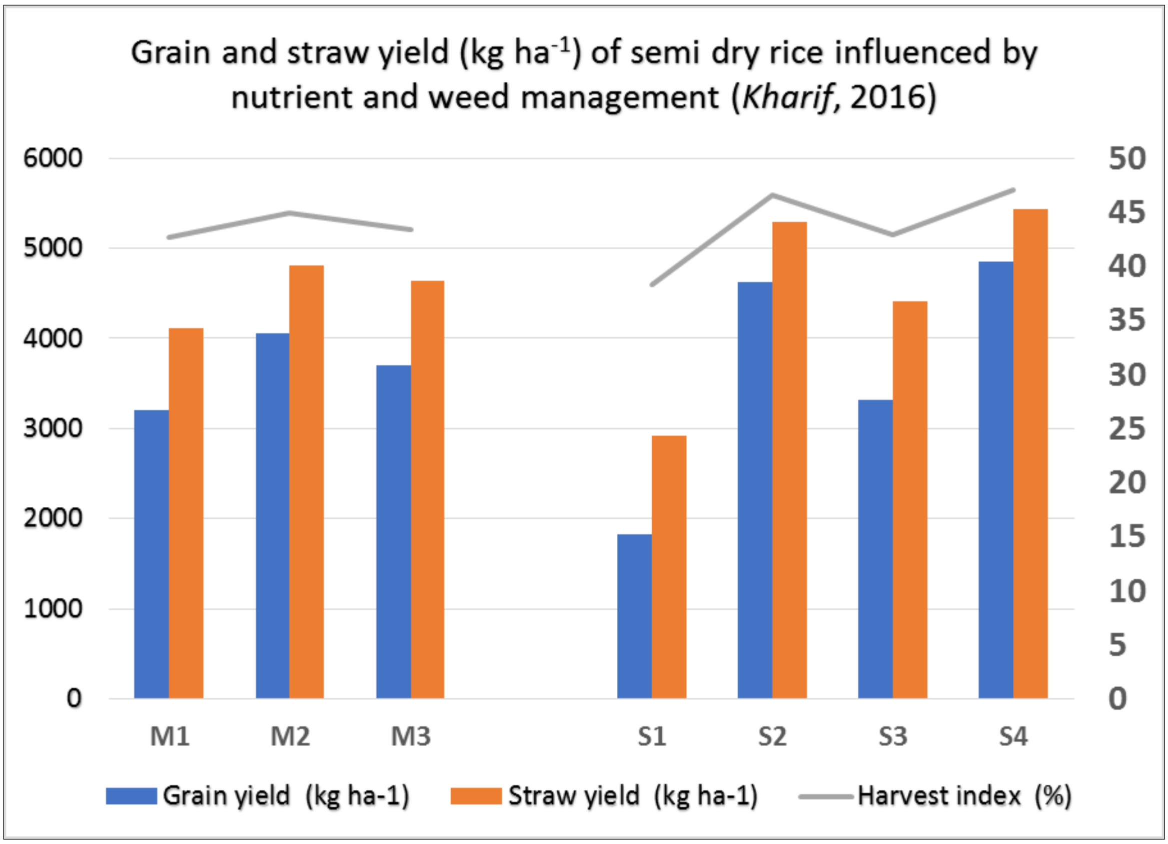

Fig 1: Grain and straw yield and harvest index of Semi dry rice as influenced by nutrient and weed management

Table 2: Energetics of semi dry rice influenced by nutrient and weed management (*Kharif*, 2016 and 2017).

Treatments	Energy input (MJ ha^{-1})	Energy output (MJ ha^{-1})	Net energy (MJ ha^{-1})	Energy use efficiency (%)	Energy productivity (Kg MJ^{-1})	Energy intensity in Economic terms (MJ Rs^{-1})	Energy intensity in Physical terms (MJ kg^{-1})
Main plots: Nutrient Management							
M_1	28125	104010	75884	3.70	0.11	3.88	4.18
M_2	26405	126602	100198	4.79	0.15	3.40	3.31
M_3	28062	118387	90325	4.22	0.13	3.57	3.78
Mean	27531	116333	88802	4.23	0.13	3.62	3.76
S.Em±		2620	2620	0.09	0.003	0.09	0.15
CD @5%		10287	10287	0.37	0.01	0.34	0.61
Sub plots: Weed Management							
S_1	27263	66054	38791	2.43	0.07	2.42	5.96
S_2	27382	141501	114119	5.18	0.17	4.46	2.78
S_3	27915	111318	83403	4.00	0.12	3.23	3.59
S_4	27564	146458	118895	5.33	0.18	4.35	2.71
Mean	27531	116333	88802	4.23	0.13	3.62	3.76
S.Em±		1753	1753	0.06	0.003	0.06	0.14
CD @5%		5210	5210	0.19	0.01	0.19	0.42
Interaction							
M × S							
S.Em±		3037	3037	0.11	0.01	0.11	0.25
CD @5%		9023	9023	0.33	0.01	NS	NS
S × M							
S.Em±		4287	4287	0.15	0.01	0.15	0.30
CD @5%		12796	12796	0.46	0.02	NS	NS

Nutrient Management

M_1 – 100% RDF

M_2 – 75% RDF + 25% N through Vermicompost

M_3 - 75% RDF + 25% N through FYM

Weed Management

S_1 - Control

S_2 - Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* hand weeding at 20, 40 DAS

S_3 - Bispyribac sodium 10 SC 25 g ha^{-1} (Early PoE) *fb* (Fenoxaprop-p-ethyl 62.5 g ha^{-1} + 2, 4 – D 80 WP 0.5 kg ha^{-1}) at 35-40 DAS

S_4 - Bispyribac sodium 10 SC 25 g ha^{-1} (PE) *fb* (Pyrazosulfuron ethyl 10 WP 25 g ha^{-1} + 2, 4 – D 80 WP 0.5 kg ha^{-1}) HW at 50 DAS

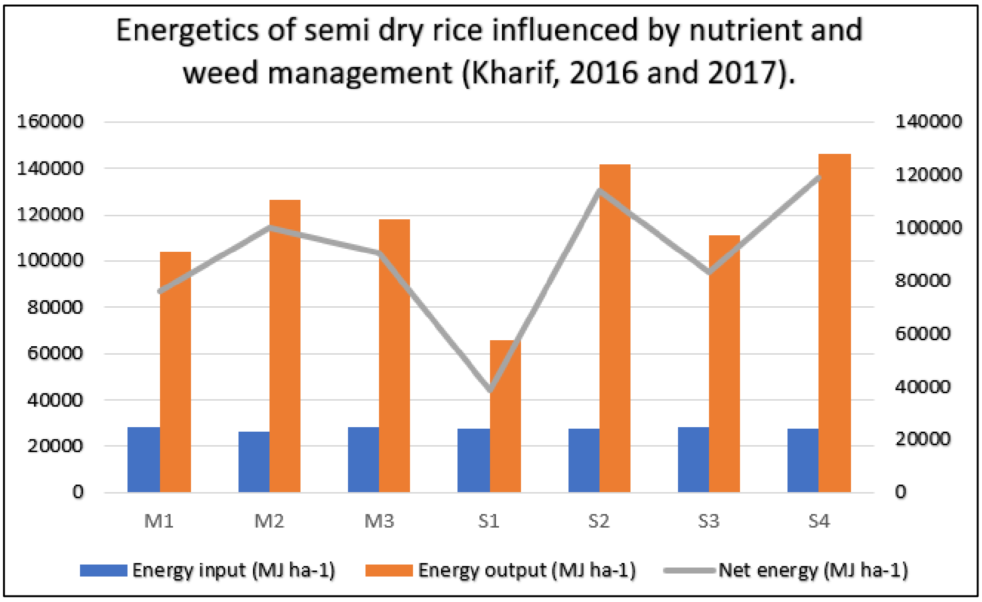

Fig 2: Energy input, energy output and Net energy gain of Semi dry rice as influenced by nutrient and weed management

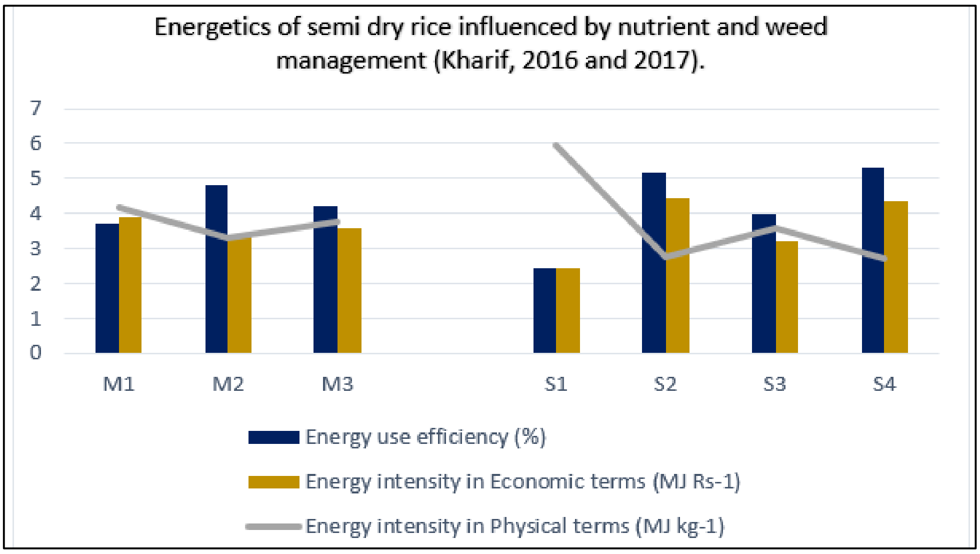

Fig 3: Energy Use efficiency, Energy intensity in Economic and Physical terms of semi dry rice as influenced by nutrient and weed management.

Appendix

Energy equivalent values of various agricultural inputs in semi dry rice experiment

Input		Energy coefficient	Unit
Machinery	Disc harrow	62.7	MJ kg^{-1}
	Rotovator	23.2	MJ kg^{-1}
	Cultivator	20.72	MJ kg^{-1}
	Sprayer	0.941	MJ kg^{-1}
	Sickle	22.4	MJ kg^{-1}
Irrigation	Diesel	56.3	MJ l^{-1}
	Water	1.02	m^3
	Electricity	11.93	k W h
	Pump	0.382	k W h ha^{-1}
Manual labor	Men	1.96	MJ man h^{-1}
	Women	1.56	MJ man h^{-1}
Manures and fertilizers	Vermicompost/FYM	0.30	MJ kg^{-1}
	Nitrogen	60.6	MJ kg^{-1}
	Phosphorus	11.1	MJ kg^{-1}
	Potassium	6.7	MJ kg^{-1}
	$FeSO_4$	20	MJ kg^{-1}
	$ZnSO_4$	20.9	MJ kg^{-1}
Pesticides and herbicides	2, 4- D	107	MJ kg^{-1}

	Fenoxaprop-p-ethyl	561	MJ kg^{-1}
	Bispyribac sodium	365.4	MJ kg^{-1}
	Pyrazosulfuron ethyl	518	MJ kg^{-1}
	Carbofuran 10 G granules	454	MJ kg^{-1}
	Chlorantraniliprole	228	MJ kg^{-1}
Seed	Seed	15.2	MJ kg^{-1}
Output			
Grain	Grain	14.7	MJ kg^{-1}
Straw	Straw	13.8	MJ kg^{-1}

4. Conclusion
Semi dry rice performed better with the conjunctive use of organics and inorganics as compared to sole inorganic fertilizers. Integration of pre-emergence, post emergence herbicides along with hand weeding had created favourable environment and resulted in enhanced grain and straw output and energy saving.

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